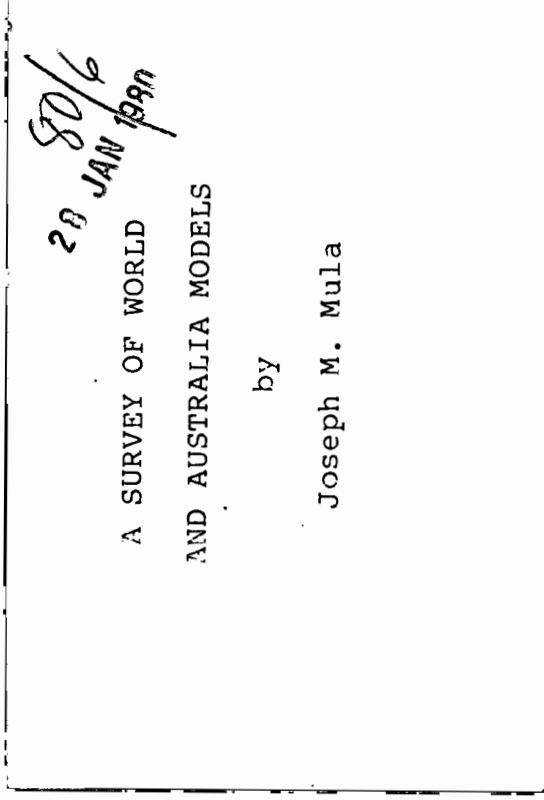




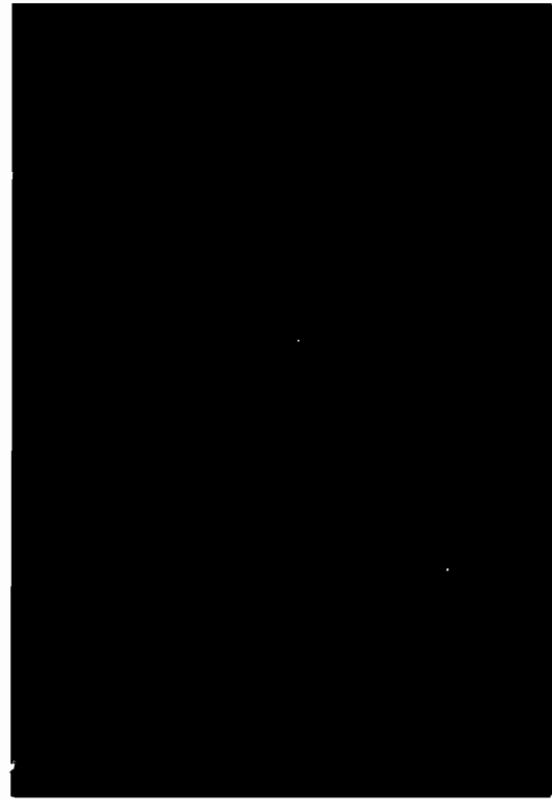
AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT (AREA) MODEL

A study by the Department of Science and the Environment in
consultation with Commonwealth departments and agencies



*The views expressed in this paper do
not necessarily reflect the opinions
of the Department of Science and the
Environment, nor of the
Australian Government.*

SARUM is a world econometric model developed by the System Analysis Research Unit of the UK's Department of the Environment, in which prices do not adjust to equilibrate supply and demand in each period, but rather recognise the many factors that inhibit instantaneous clearing of markets. The world can be regionalised into twelve regions and a number of industrial and agricultural activities.



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A SURVEY OF WORLD
AND AUSTRALIA MODELS

by

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Environmental Studies Paper, AREA-6, Canberra, March 1979

AREAM is the Australian version of SARUM for the analysis of Australian Resources and Environmental Assessment. The project was formulated in the light of a need to assess the impact of world change on the development of the Australian environment and its natural resources. In order to be able to look at environmental factors, SARUM is extended by the addition of an environment sector and the demographic sector is endogenised.

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INTRODUCTION

A number of macro-modelling studies have been and are being conducted throughout the world and also in Australia. This paper attempts to bring together these studies although it cannot be considered comprehensive. The author would appreciate hearing of any other modelling studies.

A deliberate omission from the list of Australia models is the Australian Resources and Environmental Assessment Model (AREAM) which forms the core of the project from which this series of papers emanate. The model is based on the Systems Analysis Research Unit Model (SARUM), described herein, but with certain modifications which are the subject of other papers in this series.

Most of the information on world models described in this paper has come from published material but some information has come from private communications. Description of the Australia models has also come from these two sources and each source has been given the opportunity to comment on the description herein. To all those who took the time to comment on and improve the paper, I thank you.

I. WORLD MODELS

1. LIMITS TO GROWTH MODEL

Of all the world models that are presently available or that have been developed up to now, the work of Jay Forrester and then of Dennis and Donella Meadows is still the most popularly known. Through the publication of *World Dynamics* in 1971 and *Limits to Growth* in 1972, under the auspices of the Club of Rome, world leaders were moved to instigate world modelling exercises of their own in order to either refute or agree with the fundamental Malthusian conclusion.

The purpose of this study was to investigate trends in major global concerns, namely growth in industrialisation and population, malnutrition, depletion of non-renewable natural resources and environmental degradation. Through a publication of their findings they wanted to draw attention to these concerns so that an effort could be made to reduce present growth trends.

Unlike most other global models discussed here the Forrester/Meadows model's consider the world as a single economic and social unit. It is this aggregation that came in for a tremendous amount of criticism. A similar degree of aggregation is applied to the sectors which describe this one-region model of the world. These sectors representing industry and services, agriculture, natural resources, the environment and population also came in for a great deal of criticism, not only on structural grounds but also in relation to the data used.

The model was constructed using a technique called *System Dynamics* developed by Forrester at MIT. Great emphasis is placed on the dynamic nature of the world system.

This is modelled using a set of feedback loops expressed as a system of difference equations comprising many simultaneous links. The model is run over the time period 1900 to 2100.

More detailed information on the model may be found in the following publications:

- . Forrester, J., *World Dynamics*, Wright-Allen Press Inc, Mass, 1971.
- . Meadows, D.H., Meadows, D.L., Randers, J., and Behrens II, W.W., *The Limits to Growth*, Potomac Associates, London, 1972.
- . Meadows, D.L. et al, *Dynamics of Growth in a Finite World*, Wright-Allen Press, Mass, 1974.

2. STRATEGY FOR SURVIVAL MODEL

The Strategy for Survival modelling project is a follow-on to the Forrester/Meadows work and is the second major project to receive high level support from the Club of Rome. The project grew out of a desire by the Club to conduct a follow-up to the Forrester/Meadows work that would gain a wider acceptance. In this project an attempt was to be made to look at the world as interdependent regions, focussing on more direct development policy recommendations, and at the same time attempting to incorporate solid data as well as the theories and frameworks of relevant disciplines. The project was commenced in late 1972 under the direction of Mihajlo Mesaravic of Case Western University in the United States and Edward Pestel of the Technical University of Hanover, West Germany a member of the Executive Committee of the Club of Rome.

The stated objectives of the project was to develop a scientifically based computer model of the World development system as it affects and is affected by man, and to assess

alternative sequences of events which might take place in the future, searching for possible solutions of various problems through the use of their decision-aiding tool, the model.

Regionalisation of this model as is presently documented falls into ten divisions. These regions are North America, Western and Southern Europe, Japan, South Africa and Australasia, USSR and Eastern Europe, Latin America, North Africa and Middle East, Other Africa, South and South East Asia, and Communist Asia. The Regionalisation has been based on shared traditions, history and style of life, the stage of economic development, socio-political arrangements and the commonality of major problems foreseen for the nations. There is flexibility in regional structure in that the model can operate on a few highly aggregated regions or can be expanded for the examination of specific national issues, the largest expansion attempted so far being seventeen regions.

Within each region of the model there are a number of sub-models. These sub-models represent the different strata of the world system, namely the geophysical, ecological, technological, economic and demographic. The sub-models which represent these strata are the economic, food, energy, pollution and demographic sub-models. Interaction between regions is via trade flow share matrices for food, energy, machinery and other foods, with exogenously specified aid flows.

One of the objectives of the study was to develop a model that would withstand the rigours of scientific scrutiny, thus not drawing the extent of criticism of the methodology used by the *Limits to Growth* study. However, like its predecessor the methodology employed is quite distinctive. It is based on multilevel hierarchical systems theory developed by Mesaravic and his colleagues at Case Western's Systems Research Center and first revealed to scrutiny at a seminar organised by Dennis Meadows in 1972 (at which Edward Pestel was present). Briefly stated, multilevel heirarchical systems theory as

applied to world modelling is an argument for the inclusion of sub-models of diverse scientific disciplines in one heterogeneous system. In the structure of the world there are a number of strata. First there are the physical phenomena and relationships, such as climate, mineral concentrations, geography, that together form the geophysical stratum. Secondly, the relationships of living organisms form the biological stratum. Human activities in obtaining and allocating scarce resources form the fourth stratum, the economic stratum. The remaining two strata deal with so called group interactions and the individual. Despite the importance attached to this hierarchical systems approach the dominance of the economic stratum is apparent when it is realised that all the other sub-models are linked directly and almost exclusively to the regional GNP model. The economic, biological and geophysical causal strata are represented by computer coded deterministic equations. The norms and decision strata are simply the designs and preconceptions of any individual or group using the model as a planning or research tool. The model is run over the period 1975 to 2025.

More detailed information on the project and model may be found in the following publications:

Mesaravic, M. & Pestel, E., *Mankind at the Turning Point*, Hutchinson & Co Ltd, London, 1975.

Mesaravic, M. & Pestel, E., *Multilevel Computer Model of World Development System*, 6 volumes, IIASA Symposium Proceedings, Laxenburg, 1974.

3. THE FUTURE OF THE WORLD ECONOMY STUDY

The United Nations world input-output model was constructed by a research team led by Wassily Leontief, Anne Carter and Peter Petri, at several universities in the United States. It forms part of the United Nations study on

the impact of prospective economic issues and policies on the international development strategy initiated in 1973.

The stated purpose of this study is to investigate the interrelationships between future economic growth and environmental issues, which include questions of natural resource availability, the degree of pollution associated with goods and services and the economic impact of abatement policies.

In this model the world is divided into fifteen regions, the countries being grouped on the basis of homogeneity in the economic variables, particularly gross national product per capita. Further sub-division accounts for geopolitical factors, such as proximity and political ties, the presence or absence of natural resources and the form of the economy, planned or market. The developed countries comprise eight regions: North America, Western Europe (high income), USSR, Eastern Europe, Western Europe (medium income), Japan, Oceania and South Africa. Developing Group 1, those which have major mineral resources is composed of three regions: Latin America (low income), Middle East oil producers and tropical Africa. Development Group 2 consists of medium income Latin America, centrally planned Asia, other Asian and arid Africa.

Forty-eight sectors make up this input-output model, the majority of which are industrial and service type sectors (26) with four sectors for agricultural activity, nine being classed as mining of which three are energy mining, eight types of pollutants and a trade and service sector.

From a methodological point of view the model is a linear static input-output model. The coefficients for the input-output table are derived from existing country studies of the structure of production. The changes in the elements of the input-output matrix are determined from the results of cross section regressions using an individual coefficient as a

dependent variable and gross regional product per capita as an independent variable. Given these technical coefficients, the availability of physical resources, and growth rate of gross regional product, results are generated for a sector of final goods output, employment and capital needs. Therefore, investment needs is an output of the model, ie the amount of real capital investment necessary to produce the exogenously specified gross regional product. At decade intervals the capital stock implied by the current level of output is compared to the previous decade ending stock of capital. The difference is the total investment required. Given levels of foreign investment, the domestic requirements are calculated and this amount of gross regional product is allocated to investment rather than production of final consumption goods. The model does not produce annual forecasts but a series of point projections in 1980, 1990 and 2000.

More detailed information on the model may be found in the following main publications:

- . Leontief, W. et al, *The Future of the World Economy*, United Nations, New York, 1976.
- . Petri, P.A., "An Introduction to the structure and application of the United Nations World Model", *Applied Mathematical Modelling*, 1 (5), 1977.
- . Menshikov, S.M., "Using the global input-output model for long term projections", *Proceedings of Fifth IIASA Symposium on Global Modelling*, Laxenburg, 1977.

4. SARU WORLD MODEL

The project conducted by the UK Department of the Environment's Systems Analysis Research Unit was prompted by two events which occurred in 1972. One was the Stockholm conference on the environment after which a UK Civil Service

interdepartmental committee was formed to consider the problems of resource scarcity, population growth and environmental damage on a global scale. In the same year, the Club of Rome released their report *Limits to Growth* and the then Chief Government Scientist, Sir Allan Cottrell, and several of his colleagues were convinced of the importance of the issues raised by the MIT team and dynamic modelling as an appropriate means of studying them. Concurrently with the formation of the interdepartmental committee, a research unit (SARU) was established under the leadership of Peter Roberts, to investigate the quantitative basis necessary to evaluate the so-called global *problematique*.

A major purpose of the model is to study the economic effects of depletion of the earth's resources. These resources may be a physically limited asset, such as the total reserves of cultivable land, or of fossils fuels, or something less definable such as the capacity of the environment to absorb and dissipate pollution. In essence the SARU team have attempted to stimulate the global economic system, including trade, and its use of natural resources.

The model is disaggregated into regions on the basis of geographic, economic or political division of the world. This disaggregation into regions depends on the objective of the particular study and is left to the user to decide. Presently there are twelve regions which are North America, Japan, South Africa-New Zealand-Australia (SANZA), EEC, European and Asian COMECON, other Europe and Asia Minor, Latin America and the Caribbean, South Asia, East and South East Asia, China, West Asia and North Africa, and other Africa. The SARU team have used a number of regionalisations for different study purposes.

As with regions, the disaggregation into sectors depends on the objective of the particular study. Each of the sectors produce a commodity as well as a by-product. A given

commodity may be produced by more than one process. The present model has had up to thirteen sectors but the combination of 12 regions with 11 sectors has been the disaggregation used most often.

SARUM is an econometric model in which prices do not adjust to equilibrate supply and demand in each period, but rather recognise the many factors that inhibit instantaneous clearing of markets. The system is represented by a set of differential equations which simulates its behaviour as time passes. Economic interaction between regions may take the form of trade and aid. Distortions from free trade from whatever cause (tariff, distance, etc) are incorporated using the concept of *trade biases*, which modify the perceived purchase price. Feedback loops govern the response of a sector to depletion. A particular feature of the model is the possible examination of the effects of the take-over of new technologies and processes. Seed sectors, which produce a small proportion of the total production of a commodity, lie dormant until their costs become competitive. The time period over which the model is run is from 1970 to 2000.

A more detailed description of the model can be found in the following publications:

- . Systems Analysis Research Unit, *SARUM 76 Global Modelling Project*, UK Departments of the Environment and Transport, HMSO, London, 1977.
- . Systems Analysis Research Unit, *SARUM Handbook*, UK Departments of the Environment and Transport, mimeograph, London, October 1978.

5. SIMLINK MODEL

The staff of the International Bank for Reconstruction and Development have been carrying out some in-house modelling activities for the World Bank related to its particular

organisational objectives. Along with the global *SIMLINK* model, other useful modelling work has been carried out to examine specific problems of national and regional development, some of which has been actually used in decision-making on projects submitted to the Bank for support.

The model is concerned solely with the evolution of the less developed countries. Its purpose is to analyse the prospects for growth and development of the less developed countries under alternative assumptions about growth and inflation in the developed world.

Of the model's ten regions, seven are devoted to the less developed world. This is represented by a sample of 47 countries which accounts for 76 per cent of the less developed countries' total gross national product and 70 per cent of their exports. These 47 countries are grouped into seven regions: South Asia, East Africa, West Africa, Mediterranean, East Asia, Latin America and mineral producers. The developed world is divided into three regions: West Europe, North America, and Japan/Oceania, Eastern European countries being excluded.

Fourteen sectors make up each region, built up from individual commodity models. The eleven basic goods are iron ore, fats and oils, copper, rice, sugar, beef, tin, cocoa, rubber, tea and coffee. The residual commodities are grouped into three models, namely food, agricultural non-food, and metals and minerals.

The regionalised econometric model which has been developed is designed to analyse the trade linkages between the developed and developing world with particular emphasis on the growth prospects of the latter. The focus of the model is on the relationship between developed countries' demand for basic commodities and export-led growth in the less developed countries. Accordingly, individual commodity models are built

for eleven basic goods while aggregate equations represent trade and production of the rest of the commodities. Growth rates in the developed regions are set, along with world inflation, petroleum prices and north-south capital transfers. Using the commodity models for the major primary exports of the developing countries, prices, volumes and export earnings are calculated for each of the seven regions; manufacturing and service exports from less developed countries are projected on the basis of OECD growth. A simple growth model relates growth of imports to growth of output and investment. The model solves for the level of gross domestic product which equates total imports with the sum of export earnings and capital inflow for each region. The *SIMLINK* model is not a forecasting device but has been designed to analyse trade linkages and growth prospects of developing countries under different assumptions.

Some publications on the model are as follows:

- World Bank, "The SIMLINK Model of Trade and Growth for the Developing World", World Bank Staff Working Paper No. 220, World Bank, Washington DC, October 1975.
- Hicks, N.L., "A Model of Trade and Growth for the Developing World", *European Economic Review* 7, 1976.

6. LATIN AMERICAN MODEL

The model developed at Argentina's *Fundacion Bariloche*, under the direction of Amilcar Herrera emerged as an idea from a meeting held in 1970 in Rio de Janeiro, sponsored jointly by the Club of Rome and the Institute Universitario Pesquisas do Rio de Janeiro. Preliminary results from the Forrester-Meadows model were presented at the meeting and the doomsday prophecies drew criticism of being irrelevant since two thirds of the world population already lived in desperate conditions. Financed by a grant from the

International Development Research Centre, Ottawa, Canada a model was built in which the team sees the obstacles to an equilibrated development of mankind not as shortages of minerals, but as socio-political.

Following on from this philosophy the model was built around the fact that each human being has the right to the satisfaction of a set of basic needs, these being quantified in the model as a minimum standard of food, housing, health and education. Along with fulfilling these needs, the world had to find the path of rational growth which could not be found by either capitalism or centrally planned socialism. Thus the basic needs were defined as 3000 calories per person per day, 100 grammes of protein per person per day, 98 per cent of 6 to 18 year old children to receive 12 years of education and one house per family. In obtaining rational growth, the fulfilment of social needs predominated with no profit motive and no property rights by either private or state holders.

The world is broken up into four regions, the largest includes all the developed countries: OECD, Eastern Europe, USSR, other Europe and Israel. The three developing country regions are based on uniformity of initial economic conditions and geographic proximity: Latin America, Africa and Asia.

Five sectors, make up the regional economy:

agriculture and nutrition, education, housing - the output of these three sectors being the basic needs. Sector four provides capital investment and sector five represents the non-essential consuming activities. Targets are set for each of the basic needs and the model is used to derive the optimal allocation of capital and labour to achieve these targets.

The mathematical model allocates capital and labour resources to the five sectors of the economy to maximise the life expectancy number for each region, a small sub-model being used to combine the four basic needs to predict life expectancy

at birth. The running of the model is an exercise in the applications of optimal control theory. The control variables are the functions of total labour and capital going to each sector. The objective function is the value of the life expectancy at birth for each period. While the modellers postulate the unconstrained flow of goods and resources within regions, trade between regions is precluded, mirroring the stress on the importance of autarchy. The model is run over various time periods the most common being 1970 to 2040.

Main publications on the model are as follows:

- . Herrera, A. et al, *Catastrophe of New Society : A Latin American World Model*, International Development Research Centre, Ottawa, 1976.
- . Bruckmann, G. ed., *Latin American World Modelling* Proceedings of the Second IIASA Symposium on Global Modelling, CP-76-8, IIASA Publications, Laxenburg, 1976.

7. MOIRA MODEL

The Model of International Relations in Agriculture (MOIRA) is a reduced version of an earlier model specified by Professor J. Linnemann. Originally, Professor Linnemann set out to examine whether it would be possible, within the period in which world population is expected to double to provide every human being with the material requirements for a decent human life and if so, what policies would be required to meet these requirements. Beseated by personnel problems, the group decided to concentrate on problems of food supply and distribution, the motivation in part, coming from concerns raised at the World Food Conference, held by the UN in Rome in November 1974.

The model describes the development and structure of the agricultural sector in each of 106 countries. The functioning of these sectors differ according to whether the country is a centrally planned or market economy. Development of the non-agricultural sectors is exogenous as is the growth of population. Only one final food product is produced, namely consumable protein.

Econometric complexity restricts the number of runs that may be performed. The model attempts to explain food production as a function of the size of the agricultural labour force, the prices of other means of production, the price of the food output and natural agro-environment conditions. The market determined output price together with production and input costs determine the agricultural sectors income, this income being spent on food or non-food products. A relatively detailed international trade sector allows changes in commodity flows and changes in world food pricing to be taken into account.

The main publication on the study is as follows:

- . Bruckmann, G. ed., *MOIRA : Food and Agriculture Model* Proceedings of the Third IIASA Symposium on Global Modelling, CP-77-1, IIASA Publications, Laxenburg, 1977.

8. PROJECT LINK

There are a number of single country macro-economic models around the world and Project LINK was designed to link these modelling systems. It was conceived to improve the performance of the national models by denogenising the foreign sector. This in turn overcame a major shortcoming of national models, namely the absence of means of determining the feedbacks from international trade and capital flows.

Only member countries of OECD are included because of the emphasis of models which are already in existence. Any reference to the less developed countries and the centrally planned economics is by way of necessity and only to a limited extent at present.

The area of greatest emphasis is on international trade and flow of capital. The econometric model of the nation states are joined together to examine bilateral trade flows, equilibrium in international markets and problems arising from the transmission of business cycles across national boundaries. As the time periods of the national models are short to medium term, the aggregated world model is similarly constrained.

Publications on the project are as follows:

- . Klein, L., "Project LINK : Forecasting Economic Events", *Items*, March 1975.
- . Klein, L., et al, "Project LINK", *Columbia Journal of World Business*, 11, Winter 1976.
- . Waelbroeck, J. ed., *The Models of Project LINK*, North-Holland, Amsterdam, 1976.

9. MOISE MODEL

Like most other developed countries' modelling endeavours, this model was developed to study the major linkages between nations, by Groupe de'Etudes Prospective Internationales in France. Because national models lacked the international linkages which were becoming important, it was felt that a model should be built to explore the important area of international trade and policy issues than transcend national boundaries.

Although the world is divided into 20 regions more detailed regional disaggregation is found in the first ten, all of which are developed countries. These first ten include: United States, Canada, France, Belgium-Luxembourg, Germany, Italy, Scandinavia, Alpine Countries, Southern Europe, and Japan. The remaining regions include: Australia, New Zealand, South East Asia, Soviet Russia, Eastern Europe and China. Interest mainly lies in the industrial activities of Western Europe and the other regions only respond to the economic environment through a demand for imports or a supply of exports.

The structure of the model can be broken down into two "circuits" - an internal circuit and an external circuit. The internal circuit is an input-output model of the regional economy where the supply of all goods is fixed. With these production levels set, the inverse of the input-output matrix is used to calculate factor demands. Incomes are then determined with these as well as exogenously specified wages and capital rental rates. These incomes along with the price of goods will in turn determine the consumption of goods. Through model iteration, a point is found which will equate domestic production plus net imports with domestic consumption. The external circuit models the trade flows of goods and services. Again by the process of iteration the model is run until global excess demand for each good is zero. The model is run over a five to ten year period.

There is some unpublished documentation on the model mainly obtainable from Dr Hauss Linneman at the Free University, Amsterdam.

10. FUGI - ESCAP MODEL

Project FUGI (Future of Global Interdependence) was commenced in 1976 out of a concern of a region's increasing interdependence on the world society. The project has had support from the Japanese Committee of the Club of Rome and the

Nippon Institute for Research Advancement. The project team is divided into three groups. One group looks after the global dynamic macro-economic model (GMEM) under the leadership of Akina Onishi, Professor of Economics at Soka University; the second group developed the global static input-output model (GIOM) under the leadership of Professor Yoichi Kaya of the University of Tokyo who specialises in systems science; the third group have constructed the world metal resources model under the leadership of Professor Yutaka Suzuki of Osaka University and also a systems scientist. The focus of the research, under the continuing sponsorship of the Nippon Institute for Research Advancement, is presently centered around detailed scenarios of the future economy of ESCAP (Economic and Social Commission of Asia and the Pacific) regions. The first two models GMEM and GIOM are used for these scenarios which are being developed in collaboration with the UN-ESCAP office.

The regions which make up ESCAP are Japan, Korea, Philippines, Thailand, Malaysia and Singapore, Indonesia, India, other West and South Asian countries, Taiwan and Hong Kong, and Oceania. However the model covers the whole world which recognises the interdependence between regions of the world. It also permits the development of various scenarios of the future of ESCAP regions within the future development of other regions.

Geographic regionalisation varies for the two models. For the GMEM there are 28 regions divided into three main groups, Advanced Market Economies (AME), Developing Market Economies (DME) and Centrally Planned Economies (CPE). Because the object of the FUGI-ESCAP model is to look at the development of ESCAP regions, GIOM regions have been specifically chosen so that individual ESCAP countries can be looked at in detail with the other countries of the world aggregated. Centrally planned Asian countries are excluded from the model mainly due to lack of available data.

As with geographical regionalisation, the regional aggregation varies for both models. In GMEM there are six sectors which summarise the macro-economic determinants which are production, expenditure on gross regional product (GRP) at constant prices, profit and wages, prices, expenditure on GRP at current prices, and official development assistance and private overseas investment. Besides the last two international linkages there are also trade flows. Within GIOM there are 14 sectors which cover the major groups of the standard international classification codes for agriculture, fishery and forestry, mining, eight manufacturing industries, and four tertiary industries.

The whole structure of the FUGI-ESCAP model is unique to most global modelling exercises because it does not use only one methodology. The GMEM sub-model is a dynamic macro-economic model while GIOM is a static input-output optimisation model. With the combination of the two methodologies, the Japanese team have come up with what they term a 'T' shape structure. The horizontal axis corresponds to time which represents the dynamic macro-model GMEM, and the vertical one corresponds to the sectorial axis of the input-output model GIOM. The structure of the region's macro-economy in a specified year generated by GMEM are entered into GIOM as exogenous variables. The corresponding industrial/sectorial structures of different regions are determined as a solution to a linear programming optimization under certain restraint criteria related to the characteristics of industrial production and international trade. The total trade of a region in GMEM is estimated as a linear function of GRP while the trade of a region by sector in GIOM is estimated as a log-linear function, care being taken to make sure that outputs of both models are consistent. Projections are made over the time period 1975 to 1980.

Major publications on the project are as follows:

Kaya, Y., and Onishi, A., "Development of FUGI-ESCAP Model", paper presented to a Seminar on Long-term Projections of Economic Growth in ESCAP Member Countries, Bangkok, February, 1979.

Kaya, Y. et al, "Future of Global Interdependence - Report on Project FUGI" presented to Fifth IIASA Symposium on Global Modelling, Laxenburg, 1977.

11. OTHER MODELS AND MODELLING PROJECTS

Below is a brief description of other models and modelling projects that are being conducted around the world. The list is by no means extensive and the author would be glad to hear of any other modelling efforts.

A series of national economic demographic models have been developed by the International Labour Office (ILO) called BACHUE. The models are used to evaluate policies that can create employment and in turn remove some of the inequalities in income distribution. Changing economic effects are measured in relation to demographic structure and the feedback from this demographic change on the economic system. A number of national models have been developed by national teams in collaboration with the ILO.

Under the auspices of the US Environment Protection Agency, Peter House directed the development of the State of the System (SOS) model, designed to examine a region or a nation as a human ecosystem. To represent an ecosystem, the model has a description of the present state of the region's carrying capacity plus feedback procedures for adjusting growth as a function of resources and ecomedia utilization, as well as area-specific societal value judgements and demands which are represented by quality of life goals.

Another national model is the long-term normative model of development (MRI). This is a model of the Polish economy. Its significance stems from the fact that it is the first Eastern European model to be presented at IIASA, although a model developed in the Soviet Union is to be presented this year. The overall structure is based on control theory. It is intended that the national model will be imbedded into a global model.

The INFORUM system is similar to Project LINK except that it projects forward by ten to fifteen years. It is a system of comprehensive national input-output models linked together through an input-output trade model. Exports of 119 commodity groups from major industrial countries are intended to be modelled, with six country models already under construction or completed. The work is being carried out within each country.

Other input-output models include the Louvain general equilibrium model of world trade and the University of Bradford's model. The Louvain model looks at trade between five regions of the world economy with fifteen sector input-output tables for Latin America, Asia and Africa. The other regions are Middle East Oil Producers and Developed Countries. The Bradford model has fifty-one sectors incorporating all nations trade flows. Work carried out to date has concentrated on data collection and methodological problems.

One other interesting project is an extension of Meadows' *WORLD 3*, where Frederick Kile from Wisconsin in the United States has produced a thirty region model structurally similar to *WORLD 3*. This work is similar to a study of Australia in a world context represented by the *WORLD 3* structure. The model developed is used to analyse energy policies for Australia which promote the large scale development of solar energy.

Publications on these studies in the order considered in the foregoing discussion are as follows:

- . Blandy, R.J., and Wery, R., "Population growth and employment : BACHUE-1", *International Labour Review*, 107, 1973.
- . Rogers, G.B., Hopkins, M.S.D., and Wery, R., *BACHUE-Philippines : Population, Employment and Inequality*, Saxon House, Hants, 1978.
- . House, P.W. and Williams, E.R., *The Carrying Capacity of a Nation*, Lexington Books, Lexington, Mass., 1975.
- . Kulikowski, R. et al "Long term normative model of development, MRI", paper prepared for the Fourth IIASA Symposium on Global Modelling, Laxenburg, September 1976.
- . Nyhus, D.E. and Almon, C., "The INFORUM international system of input-output models and bilateral trade flows", INFORUM Research Report 21, University of Maryland, 1977.
- . Ginsburgh, V. and Waelbroek, J., "A general equilibrium model of world trade: Part I Full format computation of economic equilibria", Cowles Foundation Discussion Paper 142, 1975, also "Part II The empirical specification" Paper 143.
- . Ginsburgh, V. and Waelbroek, J., "A general equilibrium model of world trade : Part III some calculations of the impact of tariffs on world trade and welfare", A Report to the Centre for Operations Research and Econometrics, Universite Catholique de Louvain, 1977.

- . Bottomley, A. et al, "A fifty-one sector world input-output model" presented to Fifth IIASA Symposium on Global Modelling, Laxenburg, 1977.
- . Kile, F., "A value-driven regionalized world model", prepared for delivery to Fifth IIASA Symposium on Global Modelling, Laxenburg, 1977.
- . Mula, J.M. et al, *Solar Australia : Australia at the Crossroads*, Ambassador Press, Granville, 1977.

II. AUSTRALIA MODELS

1. APMAA - Aggregative Programming Model of Australian Agriculture

The APMAA project was commenced in 1972 at the University of New England. The project is presently under the direction of Professor John Dillon and Professor John Guise, but the project team has changed over the years, some of its members being notable agricultural economists today. It was the first major attempt to try to model both the micro and macro features of Australian agriculture. Original versions of the model were built for the wool sector which was then extended to other sectors but only for New South Wales.

In its present form the model covers all the states and territories of Australia which is broken down into a sixty-three non-urban statistical divisions with no links between divisions. Within those divisions there are 521 representative farm types. Representative farms are characterised by linear production functions, perfectly elastic supply of industrially produced factors and profit maximising behaviour under certainty.

There are six farm-types which include sheep, sheep-cereal grain, cereal grain, beef cattle, dairy and multipurpose. Each farm-type is further subdivided into a maximum of three size categories - small, medium and large.

The core of the APMAA model comprises 521 representative farm linear programming matrices (RFLP) solved sequentially by a dual simplex algorithm. The objective of the solution of the RFLP is maximisation of expected gross margin. The set of constraints for a particular RFLP can be divided into seven groups, namely land, labour feed pool, breeding units of livestock, financial, upper and lower bounds that constrain the rate of increase, or decrease, in wheat area and

livestock breeding units, transfer and miscellaneous. An additional feature to the LP methodology used is the rainfall-yield simulator. Simulated rainfall data, derived from estimated correlations over time and between regions of monthly rainfall during the past 35 years, are inserted into econometrically estimated yield equations. Planned production results are transformed to distributions of actual production by the simulator.

In the current version of the model, price expectations, yield expectations and stocks of resources are determined exogenously. Prices are discounted to allow for transport from regional centres to appropriate ports. No distinction is made between export and home consumption prices. The total land area is fixed and prices of inputs are also assumed to be given. Other assumptions are made about soil and climatic conditions and the behavioural planning rules of representative farm managers. Policy-based constraints are also included.

There are 100 activity types represented in the model which can be divided into eleven groups: grain crop, cereal crops for grazing, fodder crops, pasture, beef cattle, sheep, pig, dairy cattle, financial buying and selling of livestock and plant and miscellaneous. From these activities, results can be aggregated with respect to location, commodity, farm-type, size, region, State, and Australian totals. Examples of other aggregations carried out include planned production of commodities, relative changes in production, costs and farm incomes and distributions of net farm incomes.

A major part of the research funding has come from the Australian Wool Research Trust Fund. The residue has been met by grants from the Industries Assistance Commission, a rural research fund of the Australian Reserve Bank and the Australian Research Grants Committee. The work on the model is complete to its second stage. The data base is currently being updated

with 1976 data. Research into the theoretical basis of APMAA is being directed towards extension of the general concepts of the model. To overcome the restrictions of the comparative-static framework, it is planned to extend the model into a recursive system. Other areas of research are the accommodation of risk and endogenisation of prices.

A number of publications have been produced from the project and are cited in the latest report:

- Wicks, J.A., Mueller, R.A.E. and Crellin, I.R.,
"APMAA 7 - Project Development, Model Structure and
Applications of the Aggregative Programming Model of
Australian Agriculture", APMAA Report No 11, August
1978.

2. RPM - Regional Programming Model

The Bureau of Agricultural Economics began to use regional programming models in 1974 following a request from Cabinet for a cost/benefit analysis of the case for a superphosphate subsidy. A regional programming model was the most suitable tool to use in this situation and from this beginning a family of models of the grazing and cropping industries was developed to meet the needs of studies of which the latest is RPM. The work on the model is under the direction of Dr Onko Kingma.

RPM is basically a national model with thirteen regions. The regions have been chosen on the basis of agricultural and climatic conditions and are an aggregation of the Australian Grazing Industry Survey regions which are based on a sample of some 1200 farms. Within each region there are a number of sub-matrices for the broad agricultural activities of pasture or food supply, cropping, sheep and cattle. There are also sub-matrices for labour and capital and investment.

The pasture activity is broken down into native pasture receiving no artificial fertilizers, two stages of partially improved intermediate pasture and six fully developed improved pasture, based on superphosphate application rates. Cropping activities vary according to the production intensity and the cereal which include wheat, barley, oats, sorghum, sunflowers and lupins. The sheep activities cover the traditional sheep products of wool, lamb and mutton and two types of beef, table and manufacturing, are produced from the beef cattle activities. Labour requirements for the farm activities are provided by three groups of labour utilisation activities - operator and family labour, permanent hired labour and casual labour. Capital is provided for investment in the forms of medium-term capital used for livestock and machinery purchases, and long-term capital used for structural improvements, with short-term capital excluded.

One version of the model uses recursive linear programming. However the version mainly used in policy analysis is static in nature. Both maximise a linear objective function (total net income) for agriculture's three main industries (dry land cereals, sheep and beef), subject to the following constraints: regional constraints on land, feed, livestock, labour and investment; regional behavioural constraints on expansion or contraction of land types and livestock enterprises; regional institutional constraints on investment; and non-negativity constraints. All final products are assumed to be either consumed at coastal consumption centres or enter the export trade. No distinction is made between export and home consumption prices and these prices are given. In addition the model assumes all farms by major industry within a region can be presented by one aggregate regional production unit; intra-regional trade is ignored.

Besides prices for product being exogenously determined, the cropping yields and input price of labour, plant and buildings are also given. Outputs from the model are centred on the main activities and the commodities they produce by number, weight and price. In addition, labour, capital and investment results are generated along with financial results by region, state and for the nation.

The model has been completely developed in response to requests for information from the Bureau. In its present state it has been used to study the possible effects of changes in the export market for live sheep, and for a study of the effects of productivity changes in Australian agriculture. Although the model is in use in its present state, some future developments include the testing of effects of risks on farmer decision-making in the model, the development of a compatible model of the dairy industry and the development of a macro-economic model of the Australian economy to interact with the agricultural models.

A number of publications have been produced over the last three years the latest being:

Bureau of Agricultural Economics, *A Regional Programming Model of the Grazing Industry*, Australian Government Publishing Service, Canberra, 1978.

3. IMPACT - Impact of Economic, Demographic and Social Change on the Structure of the Australian Economy

The project originated in the Industries Assistance Commission in 1975. However the need for such a study emanated from a number of government-initiated committees of enquiry, principally the *Report of the Committee of Economic Enquiry* (Vernon Report), *A Commission to Advise on Assistance to Industries* by Sir John Crawford, and the *National Population Inquiry* (Borrie Report). From the outset it was felt that

other agencies and government departments required similar analytical needs and thus an inter-agency project was developed. Originally, these included the Australian Bureau of Statistics, the Department of Environment, Housing and Community Development, the Department of Industry and Commerce and the Industries Assistance Commission. The project is under the direction of Professor Alan Powell and Professor Peter Dixon.

IMPACT is a national model which has a modular design. This design process was decided upon in order that development on the model could be carried out in parallel. Thus there are three medium term models (MACRO, ORANI, BACHUROO) and a long term model (SNAPSHOT). National income accounting for the largest aggregates is handled by MACRO along with the monetary and financial conditions. The role of the ORANI model is to decompose the large aggregates into the sectoral composition of final demand, in the process generating the outputs of 109 industry groups and determining the levels of imports and exports as well as demands for labour in nine occupational groups. The demographic and labour-force model, BACHUROO, is designed to project the supplies of labour in the nine categories by modelling educational and training programmes, occupational mobility and work force participation. The SNAPSHOT framework is designed to examine the likely effects of demographic and technological changes, and possible changes in Australia's external trading pattern on the industrial composition of the economy, the appropriate composition and requirements of the labour force, and the Australian standard of living.

A number of other modelling studies have been used as a basis for development of the IMPACT models. MACRO is based on the quarterly econometric model of the Reserve Bank of Australia. ORANI has been developed from the Johansen model of the Norwegian economy, the International Monetary Fund's multi-level exchange rate model and others. Overall the ORANI

model emphasizes interconnectedness and conditional equilibrium in which supply and demand are equal in all markets, except the labour market, given an exogenously specified macro-economic environment. The BACHUROO module is based on the International Labor Office work of the World Employment Programme and their BACHUE series of models. Some modifications have been made to remove duplication of the economic structure found in other modules of IMPACT and to reflect the particular demographic and workforce characteristics of Australia. SNAPSHOT uses mathematical programming and a number of exogenously determined policy variables to arrive at a solution to a set of conditions. Like ORANI, it is a general equilibrium model.

As the medium term modules stand at the moment they are connected by outputs from one module being exogenous inputs into others. Overall the main exogenous variables are world prices, conditions affecting migration flows and a number of policy variables. Among these are education and manpower policy, migration policy, tax rates, government spending, monetary policy, exchange rates and tariff structure. For the long term model the exogenous variables are demographic, technological and overseas trade scenarios for the snapshot year.

Outputs from the modules are very detailed and, as stated above, some form inputs into other modules. BACHUROO output centres around the composition of the population and labour force and personal distribution of income. MACRO produces aggregate investment, consumption and price levels while ORANI disaggregates these figures as well as exports, imports and rate of return on new domestic investment. Jointly with BACHUROO it will give information on the structure and level of wages and unemployment by skilled groups. SNAPSHOT also produces consumption, investment and output for the snapshot year 1990 as well as trade, cost structures, labour market and gross national product figures.

The complete project is government funded through the Industries Assistance Commission (IAC) and other departments and agencies. A number of modules have been completed, namely MACRO, ORANI and SNAPSHOT with BACHUROO almost completed. The modules have also to be interlinked. Documentation of the project runs into some 84 publications which are available from the IAC. For an overview of the project see:

- Powell, A.A., *The IMPACT Project: An Overview*, March 1977. First Progress Report of the Impact Project, Volume One, Australian Government Publishing Service, Canberra.

4. End-Use Analysis of Primary Fuels

The Department of National Development commenced work in this area in 1976. In April of 1978 they published their first document on end-use analysis called *Demand for Primary Fuels, Australia 1976-77 to 1986-87*. Their latest document is a compendium to the demand publication and brings up to date the previous 1974 report of the former Department of Minerals and Energy.

Both national and state projections are generated.

Within each state there are forty-four industrial category demands by sixteen primary fuel types. Separate projections are made for transport and non-transport fuels.

Within transport fuels, motor spirit projections are generated by a detailed mathematical model which incorporates a motor vehicle demand projection, based on an econometric model developed by the IAC, to project changes in age, size, fuel economy of motor vehicles and vehicle utilization. Demand functions for each of the other transport fuels were estimates using relatively simple econometric methods modified by information supplied by airline, railway, shipping and other transport organisations. For non-transport fuels, other than

electricity generation, information received from the fuel survey and econometric techniques were used to estimate energy demand. Growth in electricity demand was projected based on a Departmental estimate of 1.225 for the future income elasticity of demand for electricity. The projection of total primary energy demand obtained by summing the demand for fuels was constrained to conform with a projection derived from an econometric function for total primary energy demand.

Assumptions were made in deriving the projections, the most significant being that the rate of economic growth over the projection period will be four per cent. The price of petroleum products are based on the prior policy that indigenous crude oil should move to import parity. Other prices were assumed to show only slight growth in real terms. Fuel economy of new motor vehicles was assumed to improve by up to thirty per cent over the period as a result of technological advances. The industrial energy mix was assumed to remain constant over the period. Finally there were no physical constraints on the supply of fossil fuels and the development of presently known, but as yet undeveloped, fuel and energy sources will not have a significant impact on demand patterns over the period.

The work has been completed and the end use tables are published in the following document:

- . Department of National Development, *End-use Analysis of Primary Fuels Demand Australia 1973-74 to 1986-87*, Canberra, 1978.

5. IMP - The Institute Multi-Purpose Model

The IMP model building team was formed in 1973 in response to a need for a long-term outlook of the Australian economy expressed by private enterprise. This led to the Institute establishing an econometric forecasting service. For .

the first two years, the principal objective was the development of a 20 to 25 sector model of the Australian economy and the construction of detailed agricultural and demographic sectors.

In its present form the model is national in scope. An international module based on a fifteen region disaggregation, producing inputs for, but not limited to, the Australian model has also been developed. The international model is intended to include the United States, Japan, United Kingdom, Germany, France, Italy, residual EEC, residual European EEC, Canada, OPEC, developing Asia Communist Block, Brazil and the rest of the world. Within each region there is a demographic sector and four other sectors, agriculture, manufacturing, community services and a residual sector which consists of building and construction, transport, communication, and finance and commerce. Not all these individual region models are completed. The disaggregation into States in the state module has just commenced.

There are six other modules which describe the Australian model. The main module contains functions for twenty-two private consumption categories, government current and capital demand functions not included in other modules, housing demand functions, functions determining all the required implicit final demand deflators and all the miscellaneous functions for variables which are required to close the system. In the demographic module functions are included to determine age-specific mortality rates, fertility rates, immigration and emigration rates, marriage and divorce rates and population levels, all in age-specific terms. The finance module contains relationships generating the income account, capital account and flow of funds accounts for twenty-two institutions covering banking, insurance, finance, building societies, corporate trading and the rest of the world transactions. The government sector is also included showing various tax revenue and expenditure functions. In the

household sector the determination of both wage and salary and unincorporated enterprise income is derived by summing the income applicable to these categories at the seventy-two sector level with dividend income being derived from total company income. The energy-transport module contains demand functions for freight and passenger transport in terms of the rail, road, bus and tram, and ship and air transport. The energy demand categories are oil, broken down into aviation fuel, motor spirit, heating oil, automotive distillate, industrial diesel fuel, fuel oil, bunker fuels and miscellaneous products; gas; electricity; and coal, broken down into black and brown. Energy demand functions for each of the energy types are supplied separately for the household, agricultural, mining and commercial sectors and for nine manufacturing sectors of extracting, engineering, vehicles, foods, textiles, paper, chemicals, oil refinery and other manufacturing.

A seventy-two by seventy-two matrix forms the centre of the industrial activity module. The industrial activities can be grouped into seven agricultural, four mining, forty-four manufacturing and seventeen tertiary sectors. The tertiary sectors are not as extensive as the manufacturing which contains functions for total demand, exports, export prices, imports, import prices, domestic demand, home prices, labour demand, capital demand, material demand, wage rates, capital and material prices. For the agricultural, transport, communication, coal and crude petroleum activities, the respective costs, prices, factor demands and output will be determined in other modules and inserted exogenously into the industrial activity module. There is also further disaggregation for the metallic minerals activity into iron ore, zinc, copper, lead, tin, and bauxite, and the corresponding processed forms of these metals. The agricultural module contains question which determine output, prices, exports, costs and farm income in eight product groups: wheat, other grains, sugar cane, other crops, wool, cattle, sheep and lambs, and other livestock.

IMP contains a mix of methodologies in its construction. This is in line with the modelling team's philosophy that any econometric model should rely on a blend of theoretical specification and empirical estimation and that neither should dominate. Through the team's network of industrial contacts, market views are taken into consideration in determining estimations. Linear programming (LP) is used as a means of coping with the introduction of new energy forms such as solar and synthetic crude oil, for example. The model adopts the Keynesian view that the appropriate market clearing mechanisms are government policy instruments, not neoclassical market mechanisms.

As stated earlier, the modules are linked by exogenous inputs generated from each module. The stocks in the agricultural module are treated as exogenous, no change in stocks is assumed. Factors such as weather, attacks of diseases or pests, and quality variation in factor inputs are assumed in a weather variable which is set exogenously. Policy control variables are set so that several key markets are in balance, in other words, so that relevant policy goals are achieved. These variables include tax variables, current and capital government expenditure, transfer payments, exchange rates, monetary interest rates, tariffs, subsidies, import and export quotas, private capital inflow, government borrowings domestically and overseas, and social policy changes such as increased child care expenditure to increase married women's participation in the work force.

From the discussions above the range of output is quite extensive. Results can be aggregated by industry and for the whole economy, with percentage growths calculated by year and over the period to 1990. Detailed conferences are held with subscriber members a number of times each year and it is from this membership that the Institute obtains its funds. Documentation is in the main only available to members and what has been published has been mainly in article form. This is to

be rectified this year with a number of publications already at the printers. An overview of the whole model is contained in the article:

- . Brain, P., The Institute Multi-Purpose Model: An Overview, *The Australian Economic Review*, 3rd Quarter, 1977.

6. Solar Australia

The culmination of approximately five years work was an application of a World-Australia model to evaluate alternative solar energy policies within an economy taking into consideration the competing demands for resources and world influences. Modifications to the *Limits to Growth* model were commenced in 1973 by Joe Mula as part of a Master's Degree programme. In the light of a number of criticisms levelled at the Meadows' model it was necessary to change the model structure. An Australia model was built using the modified structure and an interface which handled trade and migration to join this model with a model of the world. A further modification was carried out to the model under the direction of Ray Ward of Thames Polytechnic, London to model the flow of funds into and out of Australia. This modified model is the one used by the Foundation for Australian Resources to produce the report *Solar Australia: Australia at the Crossroads*, the project being instigated by Dr Barry Thornton, Head of Mathematical Sciences at the New South Wales Institute of Technology.

Within both the World and Australian model, there are a number of sectors, namely industry/service, agriculture and land use, non-renewable and renewable energy, minerals, population and labour force, and environment and pollution abatement. Between the two models there is an interface to model trade in food, industrial goods and services, minerals, and energy, with flow of funds and migration modelled as well.

System dynamics methodology is used for both models.

In the main the model is a closed system although there are constants, such as depreciation rates and policy variables relating to trade and migration. Output from the model is extensive but in the form of aggregate indicators such as food in kilo calories and energy in tonnes of coal equivalent.

The work was originally funded within the Thames polytechnic's research studentship programme for two years. At the end of that period the Foundation for Australian Resources commissioned Ray Ward and his associates to prepare model runs which were the basis for the report written in Australia under the direction of Mula. As a project, the work is complete and the main publications are in the forms of the following book and thesis:

- . Mula, J.M., Ward, R.A., Thornton, B.S. and Malanos, C., *Solar Australia - Australia At the Crossroads*, Ambassador Press Pty Ltd, Granville, 1977.
- . Mula, J.M., *Exploring Conflicting Views of Australia's Future Using a System Dynamics Model*, M. Phil Thesis, Thames Polytechnic, London, 1975.

7. Some Other National and Regional Models

Although the models stated below cover a range of models developed or being developed, it is by no means a comprehensive list, as some work in this area is unpublished. The author would appreciate hearing from other modelling teams.

A model of the Australian Economy developed by the Reserve Bank has been used by IMPACT for its MACRO module and was discussed earlier. It is one of a series that the Bank has developed from as early as 1970. In the main, most of the models developed are used for quarterly forecasts for short to medium term projections.

Another model of Australia based on system dynamics methodology and using the same structure as *The Limits to Growth* model was produced by Jay Horton of James Cook University of North Queensland in the Department of Civil and Systems Engineering. The model does not have a world interaction capability although migration and trade flows are included. The simulation time is over the period 1950 to 2020.

Using the system dynamics methodology, Professor Kevin Stark and others at James Cook University have developed simulation models of urban and regional growth. These simulation models provide an interlinking system of analysis which is designed to explore the interrelationships that exist between growth regions and their surrounding areas and hence allow evaluation of the impact of alternative policies on regional systems. Four models have been developed, namely, an interactive model for general analysis of regional impacts, a dynamic model of urban growth, a dynamic model of regional growth and a dynamic model of inter-regional behaviour. The study was initiated in 1975 under the auspices of the Cities Commission and a submission was made to the former Department of Environment, Housing and Community Development. Although the study concentrated on regions in Northern Queensland, it produced a methodology for a regional model of Australia, in terms of population, employment and services.

Using a different methodology researchers at the CSIRO Division of Building Research, Melbourne have developed a Dynamic Regional Economic Allocation Model (DREAM). The principal researchers are Karlqvist, Sharpe, Batten and Brotchie. The broad objective of DREAM is to model interdependencies between the environment (land plus other resources), and population and the economy, both between and within large regions such as labour markets, statistical divisions, or States. The model has been formulated as a tool for analysing the feasibility, consistency and trade-offs

between different national and regional objectives. In addition to the components of population and the economy mentioned, the transportation system is added. These three main components make up the regional system of DREAM. The mathematical structure of the model is represented by a set of linear constraint equations with an objective function which may be linear or non-linear depending on the choice of objective. Solution to this mathematical programming formulation, in which the constraints are linear in terms of unknown variables (level of output and level of capital investment) with a non-linear objective function (maximising total net surplus), is by iterative linear programming techniques. The program is written in FORTRAN for the Cyber 76 computer in the CSIRONET system. The first regional application involved growth strategies for Albury-Wodonga, mainly as a function of its relationship with Melbourne and Sydney. Subsequent applications have involved inter-regional studies of Western Australia and more recently Tasmania. Flows from regions under study to the rest of the State and Australia as well as the world are handled by the use of a gravity model. The time period varies but is usually no more than ten years divided into two or three periods.

Other work carried out in the urban modelling area within the former Department of Environment, Housing and Community Development (EHCD) has focussed on producing a wide range of population projections. The model was developed to estimate the future population of fourteen to twenty-five regions of Australia given assumptions about future levels of fertility and mortality rates and overseas and internal migration. A non-behavioural model utilizing these population projections was also developed by EHCD to produce projections of households and dwelling completions for five year intervals to the year 2000. In recent years this model has been used by the Indicative Planning Council.

Work in the Department of Immigration and Ethnic Affairs has been mainly centred around international passenger movement and the manpower and resource implications of changes in the level of this movement, especially in the light of changes in international air fares. Multiple regression analysis has been used to prepare short-term extrapolation of international movements of 1980. The Bureau of Transport Economics has also developed and used a model for this purpose.

Dr John Kennedy of La Trobe University has derived a dynamic programming model of world wheat buffer stock to look at alternative wheat storage policies which maximize the present value of returns for consumers, producers, a monopoly storage agency and society as a whole. The model is extended to derive optimal storage policies if production follows a stochastic cobweb process. A further development of this work by Kennedy is to disaggregate it into a four grain, three regional model, the grains being wheat, rice, maize and barley, and the regions being North America; Europe, USSR and Oceania; and South America, Africa, South East Asia and China.

Dr B.J. White of Department of Primary Industries, Queensland has completed a model for evaluation of Queensland's northern sheep industry. The work was done within the Geography Department of James Cook University of North Queensland. In this study, the model developed simulates the physical and financial performance of a typical sheep property in the northern sheep region. Major emphasis is given to behaviour of the system as determined by temporal weather variability, thus constraining the problem to decision-making in a risky physical environment. The two critical issues in this high risk environment for the region chosen were stocking policy and rainfall. The model thus developed, considered the major state variables of the system which interacted with rainfall, and stocking policy. The state variables were identified with six compartments which are modelled as sub-systems of the overall sheep property system. These

sub-systems are the soil water balance, pasture dry-matter, sheep body-weight, parasites, sheep flock and cash pool. The model uses system dynamics methodology and the program is written in FORTRAN.

A linked set of economic-energy sector models which were developed in the USA at the Brookhaven National Laboratory (BESOM) and Data Resources Inc., are being built by the Australian Atomic Energy Commission and university groups in Australia. The models will be used to examine alternative energy policies and to suggest priorities for research and development of energy technology. The set of models is made up of a large data base, a linear programming model in which the total cost of satisfying a given set of national energy demands is minimized, an input/output model of the national economy, and a macro-economic general equilibrium model.

Dr Lal Wadhwa and Professor Kevin Stark of James Cook University have developed a conceptual methodology for a system dynamics model of a national energy-environment management system. The model is to comprise twenty-one energy demand and fifteen resource supply modules with major emphasis on an oil-transport interface. Pricing, technology and environment impact models have also been developed within the one economic framework. Specific energy-environment policy options are to be simulated and alternative futures described. This framework is presently being developed by Wadhwa and Pomeroy into an integrated energy-environment systems model for Australia with a view to describing energy-environment scenarios, determining optimal patterns of energy use and formulating a national energy policy within the technological, environment, economic, social and institutional constraints. This project has received the support of ARGC.

Under the supervision of Professor Stark, a PhD student within the Economics Department, Peter Crossman, is developing an econometric model of the State of Queensland.

The model is an orthodox regional econometric model similar to several developed in the United States. It is a short/medium term model that will simulate for both validation and forecasting purposes. Particular attention will be given to the public sector, to regional stabilization and to possible linkages with a national macro-econometric model. A comprehensive State econometric data bank is being compiled.

Bruce Kuhnell of Monash University has produced a conceptual set of models which have been developed to examine the change in the components of factors of production as the rate of production of food or goods changes. These models provide dynamic time-maps of factor component growths in response to inputs of desired quality of factor components; desired stock of factor components; and production rate limits. Two examples of the factor components which can be examined using the models are: capital stock needed for the production of a given investment rate and energy flow rate needed to support a given material production rate. There are four levels in the model, the provision sub-models, factor balance sub-models, the national model and the global model. The aim of the research is to try to model the dynamics of the production function to replace the use of the Cobb-Douglas production functions.

Below are listed, in the respective order of discussion, the appropriate references for the models and research discussed above.

- . Jonson, P.D., Moses, E.R. and Wymmer, C.R., "A Minimal Model of the Australian Economy", *Research Discussion Paper 7601*, Reserve Bank of Australia, Sydney, 1976.
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- . Stark, K.P., et al, *Regional Systems Simulation Study*, A Submission to the Department of Environment, Housing and Community Development, June 1977.
- . Karlqvist, A., Sharpe, R., Batten, D.F. and Brotchie, J.F. "A Regional Planning Model and its Application to South Eastern Australia", *Regional Science and Urban Economics*, 8, 1978.
- . Shogren, R., "Population Projects for Australia by Capital City and Rest of State", Internal Working Document, EHCD, August 1978.
- . Building Division, EHCD, *A Method for the Projection of Households and Dwelling Completions 1975-2000*, Australian Government Publishing Service, Canberra, 1977.
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- . White, B.J., "A Simulation Based-Evaluation of Queensland's Northern Sheep Industry", No 10 *Monograph Series*, Department of Geography, James Cook University of North Queensland, Townsville, 1978.
- . Essam, P., Maher, K.J. and Stocks, K.J. "A Suite of Energy and Economic Models for Australia", Paper presented to *First National Conference of the Australian Institute of Energy*, February 1979.
- . Wadhwa, L.C. and Stark, K.P., "A Methodology for Modelling Energy-Environment Management System", Paper presented at the *International Conference on Systems Modelling in Developing Countries*, Bangkok, May 1978.

Kuhnell, B.T., "System Dynamics Models of Production
Factor Growth", *MMER Report No 14*, Monash
University, August 1977.

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SUMMARY OF AUSTRALIA MODELS

MODEL NAME	1. APMAA	2. RPM	3. IMPACT	4. END USE OF PRIMARY FUELS	5. IMP	6. SOLAR AUSTRALIA
Year Commenced	1972	1975	1976	1973	1973	1973
Principal(s) & Research Centre	Prof's Dillon & Buse Bureau of Agric. Dept. of New England	Dr O T Kingma et al Economics	Prof's Powell & Dixon Inter Agency Study I.A.C., Melbourne	Department of National Development	Dr P. Brain Inst. Applied Econ. & Social Research University of Melbourne	J & Mula Foundation for Aust. Res. Presently Env. Studies Branch, Dept. Science and the Environment
Geographical Region	63 Non-urban (ABS) Stat. Div.	13 Agro-Climatic Regions	National Model - may be regionalised in future; ORAN - 6 states	States & National Aggregates	Australian National Model 15 Region International Model	Australian Model World Model
Disaggregation	6 Farm Types Sheep Sheep Cereal Cereal Dairy Cattle Beef Cattle Wheat, barley, oats, sorghum, sunflowers, lupins 8 Sheep Activities 2 wool, mutton 2 lamb 8 Cattle Activities Table & Manuf. beef 3 Labour Groups Operator, Perm., Casual Capital/Investment Mod. & Long term capital plant & machinery Buildings	9 Pasture Activities Native, 2 Partial improv., 6 improved 15 Cropping Activities Wheat, barley, oats, sorghum, sunflowers, lupins 8 Sheep Activities 2 wool, mutton 2 lamb 8 Cattle Activities Table & Manuf. beef 3 Labour Groups Operator, Perm., Casual Capital/Investment Mod. & Long term capital plant & machinery Buildings	Economic/Industrial 109 Industrial Groups (ABS ASIC Groups) Demographic/Labour Force 18 Age Groupings - males & females 9 Occupational groups & mobility Education, training, workforce participation 8 Cattle Activities Table & Manuf. beef 3 Labour Groups Operator, Perm., Casual Capital/Investment Mod. & Long term capital plant & machinery Buildings	44 Industry categories 16 Classes of Primary Fuel.	Main Module 22 Private consumption categories Demographic Sex-age specific population levels Age specific labour force of male, married & unmarried females, Perm. long & short term arriv. & depart. of Aust. resid. & O/S visit. Finance - Income, Capital & Flow of funds A/C's for 22 sectors Energy - Transport 5 Freight & passenger trans. modes 24 Energy cat. by 13 demand sectors Industrial Activity 7 Agric, 4 Mining, 44 Manuf., 17 Tertiary sectors, Trade Agriculture - 8 product groups	9 Sectors Industrial/Service Agriculture & land use Non-Renewable energy Renewable energy Minerals Population & labour force Environment & pollution abatement Trade Migration
Methodology	Sequential L.P. Partial Equilib. Static, Short-med. term	Recursive L.P. (Version 1) Static L.P. (Version 2) Medium term	Econometrics - Simulation, Medium term modules & long term module	Math. model & Econometrics with some past trend anal. and consumer surveys. L/term	Econometric - Simulation Quasi - Equilibrium Short, medium & long term	System Dynamics
Exogenous Variables	1. Price expectation 2. Yield 3. Labour, plant & building inputs 4. Soil, Climate, Topology 5. Behavioural planning rules 6. Policy-based const.	1. Price 2. Yield 3. Labour, plant & building inputs 4. Soil, Climate, Topology 5. Behavioural planning rules 6. Policy-based const.	1. World prices 2. Migration flows 3. Policy-based variables Long term - 1. Trade scenarios 2. Technology scenarios 3. Demographic scenarios	1. Rate of economic growth 2. Future energy prices 3. Technology 4. Constant industry energy use mix	1. Modules linked by exogenous inputs 2. Stocks agricultural products 3. Export price index 4. Weather deviations 5. Policy control variables for Taxes, Govt. expend., international flows, Social policy, immigration	Trade policy variables Migration policy variables
Principal Outputs	Realised physical & financial results by region Can be aggregated to state or national level or by farm type or size	Realised physical & financial results by region Can be aggregated to state or national level or by farm type or size	1. Agg. invest., cons. & price levels 2. Disagg. invest., output, prices, imports, exports, balance trade 3. Size, age, skill comp. of w/force, labour demand	Demand for primary fuels by State, Industry & Fuel Type	Economic activity for 72 Industries Exports, imports, Population, Work force participation, Migration, Energy supply & demand, Mineral, Government revenue & expenditure, international economic aggregates	Economic aggregates Trade in food, energy, mineral & industrial goods Population & migration Pollution index
Funding Agency(s)	Aust Wool Research Trust Fund, IAC, Reserve Bank, ARB Committee	Bureau of Agricultural Economics	Commonwealth government through IAC, DIC, DEYA. Formally included ABS and the then DEHD.	Department of National Development	Self funding by Industrial & Government subscriber membership	Thames Polytechnic, London 1973-75 Foundation for Australian Resource 1975-77
Present Project Status	Complete under revision for 1976 data, endogenised prices	Ongoing projects, future work to include uncert. & LT macro econ. f/work	2 Med term & long term modules complete, Econ/Dem. module almost complete	Completed	6 International modules completed, remainder to be done. States module to be done.	Completed